

Application No.: 10/035,056

Docket No.: JCLA8425

REMARKS**Present Status of the Application**

The Office Action mailed February 25, 2003 rejected all presently pending claims 1-10. Specifically, claims 1, 3, 7-8 and 10 were rejected under 35 U.S.C. 103(a) as being unpatentable over Bohaty (US 6,264,858); claim 2 was rejected under 35 U.S.C. 103(a) as being unpatentable over Bohaty in view of Takenaka (US 5,602,079); claims 4-6 were rejected under 35 U.S.C. 103(a) as being unpatentable over Bohaty in view of Hed (US 5,300,487); and claim 9 was rejected under 35 U.S.C. 103(a) as being unpatentable over Bohaty in view of Hed, and further in view of Wang (US 6,106,948). Reconsideration of claims 1-10 is respectfully requested.

Discussion of Office Action Rejections

Claims 1-10 were rejected under 35 U.S.C. 103(a), wherein claims 1, 3, 7-8 and 10 were rejected based on Bohaty only, and the other claims were rejected based on the combinations of Bohaty and the other three cited Patents.

This invention features with a non-linear optical material that comprises a bismuth film capable of producing non-linear optical effects including non-linear refraction and non-linear absorption. The feature is recited in independent claim 1, marked by underlines:

Application No.: 10/035,056

Docket No.: JCLA8425

"Claim 1 A non-linear optical material comprising a bismuth film capable of producing non-linear optical effects including non-linear refraction and non-linear absorption."

The entire contents of Bohaty's abstract are recited below for clarification:

"Bismuth borates in crystalline form with non-linearly optical properties. Bismuth borate crystals are used for radiation conversion. The crystal is created with non-linearly optical properties which has non-linearly optical coefficients which exceed those of crystals used hitherto in the application and which is easy, inexpensive to produce and of high optical quality."

Bohaty fails to teach or suggest a *bismuth film* with non-linear optical properties including *non-linear refraction and non-linear absorption*. What Bohaty does teach is using *bismuth borate* as a non-linear optical material for *radiation conversion*. Moreover, it is incorrect to interpret that the *non-linearly optical coefficients* that Bohaty teaches are equivalent to non-linear refraction and non-linear absorption.

As described in Example 1 of Bohaty, the frequency of the light passing through the bismuth borate crystals is doubled ($\omega \rightarrow 2\omega$). As described in Example 2, a frequency $\omega_3 (= \omega_1 + \omega_2)$ is produced with a frequency ω_1 of the incident beam and a frequency ω_2 for pumping the bismuth borate crystals. In Example 3, the bismuth borate crystals are used to produce the difference frequency ($\omega_3 = \omega_1 - \omega_2$) of two waves of different frequencies ω_1 and ω_2 . That is, the term "*radiation conversion*" is undoubtedly interpreted as *frequency or wavelength conversion* only in Bohaty. However, this very property of radiation conversion is completely different from

Application No.: 10/035,056

Docket No.: JCLA8425

the non-linear optical effects of the bismuth film.

It is well known that there are a large variety of non-linear optical effects, including *second harmonic generation*, where the frequency of the incident radiation is modified, and *the optical Kerr effect*, where the refractive index and the absorption coefficient of the non-linear material are modified. The coefficients associated with the two different effects are termed second-order non-linear optical coefficients and the Kerr constant, respectively. (See, for example, *Handbook of Optics*, vol. II, chap. 38, p. 38.5 (McGraw-Hill Inc. 1995) and *Optical Electronics in Modern Communications*, by Amonon Yariv, pp. 278-279, 642-643 (Oxford University Press, Inc. 1997).) Bohaty's bismuth borate crystals belong to the category of second harmonic generation, while the bismuth film in this invention belongs to the optical Kerr effect. In fact, the bismuth film in this invention does not alter the frequency of the incident radiation passing through it. Rather, it is the refractive index n and the absorption coefficient α of the film themselves that are modified by the incident radiation. In other words, the purpose of this invention is to produce very large changes in n and α by a small light intensity. Frequency conversion, however, is not within the scope of this invention for this property does not stem from the changes in n and α . On the other hand, the refractive index and the absorption coefficient of the bismuth borate crystals are not necessarily altered while the frequency of the incident radiation is modified. Actually, Bohaty discloses the values of the refractive indices n_1^0 ,

Application No.: 10/035,056

Docket No.: JCLA8425

n_2° , and n_3° of the bismuth borate crystals, but not the changes of these indices (col. 3 Table 2). Rather, the property of frequency conversion is due to the existence of other distinct type of coefficients in the bismuth borate crystals, namely, the so-called (second-order) “*non-linear optical coefficients*”. Bohaty specifically designates the d_{ijk} ’s as the non-linear or non-linearly optical coefficients (col. 1 line 58 and Table 1). Then, the d_{ijk} ’s are specifically defined as the second-order proportional constants relating the electric field $E(\omega)$ of the incident radiation and the non-linear component of polarization $P(2\omega)$ (col. 3 line 45-46). These coefficients (d_{ijk} ’s) are apparently different from the refractive index n and the absorption coefficient α , which are related to the capability of an optical material to converge and to absorb the incident radiation.

Furthermore, it is quite obvious that Bohaty teaches the use of bismuth borate crystals, but not a bismuth film as in this invention. This is also demonstrated in col. 4, lines 46-47 and 55-56, where Bohaty discloses using BIBO and MBIBO in crystalline form as non-linear optical materials, while BIBO and MBIBO are bismuth borates defined as BiB_3O_6 and $\text{Bi}_{1-x}\text{M}_x\text{B}_3\text{O}_6$, respectively (col. 2, lines 35-36). Bismuth borate crystals are surely different from a bismuth film, since a bismuth film is based on elementary/metallic bismuth, as generally recognized in the art, while bismuth borate crystals contain ionic bismuth only. Since the natures of a bismuth borate crystal and a bismuth film are different (cationic bismuth vs. elementary/metallic bismuth), the non-linear optical effects of the two are completely different. It is entirely unpredictable

Application No.: 10/035,056

Docket No.: JCLA8425

that a bismuth film has non-linear refraction effect and non-linear absorption effect in view of Bohaty. Therefore, it is non-obvious for one skilled in the art to figure out the use of a bismuth film for producing non-linear refraction effect and non-linear absorption effect as starting from the use of bismuth borate crystals in Bohaty.

For at least the reasons mentioned above, Applicants respectfully submit that claim 1 and claims 3, 7-8 and 10 dependent therefrom patently define over Bohaty.

Furthermore, the feature of using a metallic bismuth film as a non-linear optical (Kerr effect) material is not disclosed in any one of the other three cited Patents, Takenaka, Hed and Wang. Therefore, *at least the feature of using a bismuth film as a non-linear optical (Kerr effect) material cannot be obtained with any combination of Bohaty, Takenaka, Hed and Wang.*

For at least the same reasons mentioned above, Applicants respectfully submit that claim 2 patently defines over the combination of Bohaty and Takenaka.

For at least the same reasons mentioned above, Applicant respectfully submit that claims 4-6 also patently define over the combination of Bohaty and Hed, and claim 9 patently defines over the combination of Bohaty, Hed and Wang.

Application No.: 10/035,056

Docket No.: JCLA8425

CONCLUSION

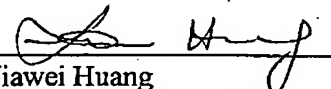
Although the disclosed material and structure may look simple, the invention is truly an original one. Actually, elemental bismuth in bulk form does not possess non-linear refraction and non-linear absorption. Only when the bismuth is made into the form of a thin film as disclosed in this invention, can it produce the extraordinary non-linear effects by merely a small light intensity. This work has been published by the applicants at a prestigious optical journal, *Optics Letters*, which accepts only novel results in optics for publication (Liu et. al., *Optics Letters*, vol. 27, No. 17, pp. 1549-1551 (2002)).

For at least the forgoing reasons, it is believed that all pending claims 1-10 are in proper condition for allowance. If the Examiner believes that a telephone conference would expedite the examination of the above-identified patent application, the Examiner is invited to call the undersigned.

Date: 6/25/2003

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Page 7 of 7

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JUN 25 2003

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